OXIDATION OF STEEL 30KhGSA
IN BOROSILICATE MELT CONTAINING IRON OXIDES

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The kinetic specifics of the oxidation of alloyed steel under a protective layer containing iron oxide are considered. The dependence of the steel oxidation rate on the concentration of Fe_2O_3 in the melt is experimentally determined.

Corrosion of steel in a glass melt can proceed with hydrogen depolarization in an atmosphere containing water vapor or with cation depolarization in the presence of variable-valence ions in the melt [1, 2]. According to the method in [3], we have investigated the oxidation of steel 30 KhGSA in a melt of the composition $10.0Na_2O \cdot 10.0CaO \cdot 53.4B_2O_3 \cdot 26.6SiO_2$ with iron oxide additives at a temperature of 1273 K.

In the oxidation of steel under a layer of an oxide melt containing variable-valence ions, the heterovalent metal ions in the melt play the crucial role in oxidation processes [4, 5]. The participation of atmospheric oxygen is reduced to the oxidation of M^{2+} ion to M^{3+} at the interface between the melt film and air. The contribution of this process to the total oxidation process can be estimated comparing the rate of steel oxidation under the melt film (approximately 0.2 mm) and in the melt volume. The average rates of oxidation of steel 30KhGSA in the melt volume and under the melt film determined, in accordance with the method in [3], in air at a temperature of 1273 K amounted to 0.28 and 20 mg/(h · cm^2), respectively. The higher rate of oxidation under the melt film is presumably related to the fact that the concentration of the higher-valence oxides that determine the oxidation process is significantly lower in the melt volume than in the film.

As a consequence of the reactions between steel and glass melt, the latter becomes enriched with the products of the reaction (M_2O_3), and with a growing concentration of Fe_2O_3 the rate of oxidation of steel 30KhGSA in a borosilicate melt can be expected to increase as well, which is corroborated by experimental data. The dependence of the rate of oxidation of steel 30KhGSA on Fe_2O_3 content obtained in accordance with the method in [3] under a testing duration of 1 – 3 min is described by the equation

$$v = A + Kw_{Fe_2O_3},$$

where $A = 0.3$; K is a coefficient characterizing the intensity

of the oxidation rate growth equal to 0.05; $w_{Fe_2O_3}$ is the mass content of Fe_2O_3.

The increased rate of steel oxidation in the iron-bearing melt is due to increased diffusion of iron ions. In this context, it is interesting to estimate the diffusion mobility of iron ions in the melt, which has been performed using the method of dissolving oxygen in a thin melt film [6].

A thin film of an iron-bearing melt was deposited on a corundum capillary by immersion. The melt was prepared by fusing glass with a preset quantity of Fe_2O_3 (10 – 20 wt.%). Next, the corundum capillary with the thin film deposited (approximately 0.2 mm) was placed into a furnace on the weight beam of the derivatograph and the increment of the sample weight in time caused by the absorbed oxygen was registered at a temperature of 1273 K (Figs. 1 and 2).

The coefficient of iron ions diffusion was calculated using the 2nd Fick law and the formula proposed in [6]:

$$D = \frac{4\delta^2}{\pi^2 r} \ln \frac{8/\pi^2}{1 - \Delta m_\tau / \Delta m_0},$$

where δ is the melt film thickness, mm; Δm_τ is the quantity of oxygen absorbed by the melt film of thickness 0.2 mm in time τ, mg; Δm_0 is the quantity of oxygen absorbed at the state of equilibrium with the gaseous phase, mg.
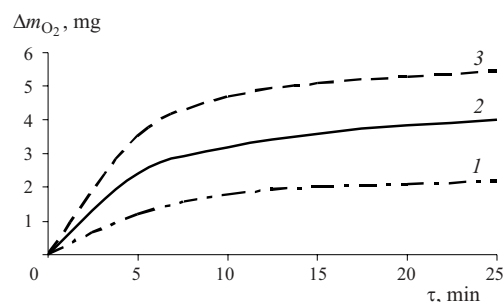
Fig. 1. Dependence of oxygen weight increment on oxidation duration: *1*, *2*, and *3*) 10, 15, and 20% Fe_2O_3, respectively.

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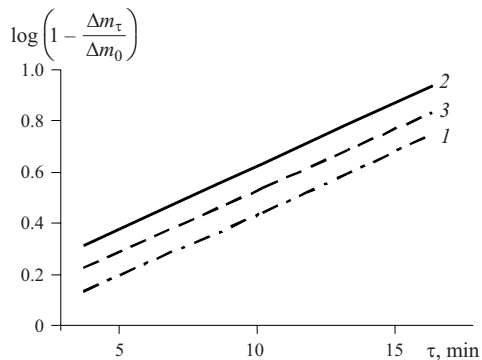
Fig. 2. Dependence of the variation rate of the weight of a steel sample on oxidation duration: *1*, *2*, and *3*) 10, 15, and 20% Fe_2O_3, respectively.

The diffusion coefficient in this case is approximately 1.3×10^{-6} cm^2/sec.

The iron diffusion coefficient in melts with obvious semiconductor properties is equal to about 10^{-4} cm^2/sec [6]. The value of the diffusion coefficient obtained by us and its weak dependence on the Fe_2O_3 content in the melt shows that at the specified concentrations of Fe_2O_3 the semiconductor properties of the vitreous composition $10.0Na_2O \cdot 10.0CaO \cdot 53.4B_2O_3 \cdot 26.6SiO_2$ at the temperature of 1273 K are weakly expressed.

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